DECLARATION

I, Toshiharu INOUE of Yakohama, Japan, the translator of the Japanese Application Ser. No. 0005244, do hereby certify to the best of my knowledge and belief that the herewith enclosed is a true translation into English of the corresponding copy of the document which has been filed with the Japanese Patent Office on March 1, 2001, with respect to an application of Letters Patent.

Signed, this 24th day of June 2002

Tm. Inoue

Toshiharu INOUE

Literal Translation of
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for Ricoh Application EPP01-574

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OPTICAL RECORDING MEDIUM, AND METHOD FOR OPTICALLY RECORDING AND READING OUT
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[List of documents attached]

[Name of document] Specification 1

[Name of document] Drawings 1

[Name of document] Abstract 1

[Generic authorization No] 9909722

[Proof reading] Required

[Name of Document] Specification

[Title of the Invention]

OPTICAL RECORDING MEDIUM, AND METHOD FOR OPTICALLY RECORDING AND READING OUT

[What is claimed is:]

[Claim 1]

A method for selecting an optimum recording power to suitably carry out read/ write/ erase operations of information data on a rewritable phase-change optical recording medium through the phase change induced in a recording layer included in said recording medium by laser beam irradiation, said recording layer essentially consisting of Ag, In, Sb and Te elements, comprising the steps of:

writing a series of information data, as test recording runs, with recording power of laser beam consecutively varied in a range of 15 mW to 18 mW to thereby generate a recorded pattern including low and high reflective portions;

reading out signals from said low and high reflective portions on said recording medium to obtain recorded signal amplitude, m, corresponding to said recording power, P;

calculating a normalized gradient, g(P), using an equation,

$$g(P)= (m/\Delta m)/(P/\Delta P),$$

where ΔP is an infinitesimal change in the vicinity of P, and Δm is an infinitesimal change in the vicinity of P;

determining an optimum recording power, after judging an adequacy of magnitude of said recording power based on thus calculated normalized gradient, g(P);

selecting a specific number, S, from the numbers in the range of 0.2 to 2.0 based on said calculated normalized gradient, g(P);

obtaining a value of said recording power, Ps, which coincide with said specific number, S, presently selected;

selecting a specific number, R, based on thus obtained recording power, Ps, from the numbers in the range of 1.0 to 1.7; and

multiplying said recording power, Ps, by said specific number, R, whereby an optimum recording power, P_0, is obtained.

[Claim 2]

A phase-change optical recording medium utilized in said method claimed in claim 1, comprising a recording layer, wherein said recording layer contains information recorded in advance therein corresponding to said S and R values specified by said method as claimed in claim 1.

[Claim 3]

The phase-change optical recording medium according to claim 2, wherein $1.2 \leq S \leq 1.4$ and $1.1 \leq R \leq 1.3$.

[Claim 4]

A phase-change optical recording medium utilized in said method claimed in claim 1, comprising a recording layer, wherein said recording layer contains information regarding P_t value recorded in advance therein, said P_t value corresponding to said optimum recording power, P_0, specified by said method as claimed in claim 1.

[Claim 5]

The phase-change optical recording medium according to

anyone of claims 2, 3 and 4, wherein said recording medium is recordable at a recording velocity ranging from 4.8 m/sec to 14.0 m/sec.

[Detailed Description of the Invention]

[0001]

[Technical field of the Invention]

This patent specification relates to a method and a rewritable information recording medium for implementing recording, reproducing and rewriting operations of information data, which is for use in optical memory devices such as, for example, compact disks.

[0002]

[Background Art]

A method for recording information signals on an optical recording medium by a write/readout apparatus is known, as disclosed previously in Japanese Patent Publication 63-29336, for example, including the steps of scanning energetic beam spots such as those from laser source over the recording medium while irradiating, and modulating the intensity of the spots corresponding to the information signals, to thereby achieve the information recording. Also disclosed in the publication is the method for determining optimum recording conditions regarding the power, pulse width and so forth, of the recording laser beams, by reading out the signals recorded on the medium, and by subsequently monitoring the width of readout signals and the length of recorded marks.

However, it is considered difficult in practice for the following reasons to always determine optimum conditions by this method even after utilizing information signals actually recorded on the recording medium by conventional write/ readout apparatuses.

There described in the above disclosure is the method which utilizes the width of readout signals as the representative value and monitors the width (i.e., the difference in signal level between the signals from non-recorded media portions and from recorded portions), whereby the conditions optimum for respective write/ readout apparatuses are obtained.

However, the width of readout signals changes not only with recording power, but also with other parameters such as a numerical aperture of the optical system, rim intensity (i.e., spatial intensity distribution of laser beams on incidence onto a collimator lens), the size and shape of beam spots, and dirty optics and its change with time, and other similar factors.

Due to the above noted dirty optics, for example, the disparity in optical efficiency generally results as much as 20 % to 40 % among the optical systems in respective write/ readout apparatuses. Therefore, it should be noted that the value determined as the optimum recording power may be affected considerably by these parameters.

It has been thus quite difficult in practice to determine the optimum recording power with an enough accuracy (e.g., approximately ± 5%). As a result, difficulties have been encountered in recording media production, for example, in that deviations in the effect of media recording are found among

write/ readout apparatuses for the same laser power. This necessitates additional minute adjustments of recording power for each apparatus, that causes drawbacks such as, for example, the decrease in the productivity of recording media.

In addition, the determination in advance of the optimum power has not been so effective, because of possible damages caused by excessive laser power during test writing.

That is, the rewritable medium should normally have advantages due to its characteristics as the writable media, in which, after determining an appropriate laser power level from test recording made on recording tracks, data recording can be carried out with the thus determined power onto the same recording racks either erase/ write or overwrite step, which is in contrast to write once media for which extra tracks exclusively for test writing are needed to determine the power level in advance.

In practice, however, the above advantages have not been so effective, since damages to the recording tracks are often caused by the excessive level of laser power during the test recording. As a result, extra tracks exclusively for test writing have to be provided in practice even for these writable recording media, to thereby result in undue waste of recording tracks, or recording area.

The present inventors have previously proposed an improved method for determining optimum recording power, in that the power is suitably determined either without being affected by both amplitude of recorded signals, m, and recording power, W, or without being affected by the amplitude alone.

In addition, the optimum recording power can be determined with relative ease in this method with a sufficient accuracy particularly for practical use in write/readout apparatuses devised for the mass production. Further, the addition of the above mentioned extra tracks are obviated and the accuracy of determined optimum laser power has been increased.

It has been realized by the present inventors, however, further improvements are yet to be made to achieve more efficient information recording, particularly for the range of recording power as high as 15 to 18 mW.

[0003]

[Problems to be solved by the Invention]

In the read/ write/ erase operations of information data, it is the object of the present disclosure to provide a method and an optical recording medium, effectively implementing recording steps at recording beam power in the range of as large as 15 mW to 18 mW, when a series of information data are recorded with recording power, P, of laser beam consecutively varied.

[0004]

[Means for Solving the Problems]

The present inventors rigorously examined to improve previous methods, and have found the method to thereby lead the present disclosure, in which a series of information data can be recorded effectively, as test recording runs, with recording power of laser beam consecutively varied in a range of 15 mW to 18 mW,

and to generate a recorded pattern including low and high reflective portions.

A method for carrying out recording and reading out operations of information data, and an optical recording medium to be used in the method, are disclosed herein, which will be detailed as follows. Namely,

(1) the method for selecting an optimum recording power including at least the steps of:

writing a series of information data, as test recording runs, with recording power of laser beam consecutively varied in the range of 15 mW to 18 mW to thereby generate a recorded pattern including low and high reflective portions;

reading out signals from the low and high reflective portions on the recording medium to obtain recorded signal amplitude, m, corresponding to the recording power, P;

calculating a normalized gradient, g(P), using the equation, $g(P)= (m/\Delta m)/(P/\Delta P)$, where ΔP is an infinitesimal change in the vicinity of P, and Δm is an infinitesimal change in the vicinity of m; determining an optimum recording power, after judging adequacy of the magnitude of the recording power based on thus calculated normalized gradient, g(P);

selecting a specific number, S, from the numbers in the range of 0.2 to 2.0 based on the calculated normalized gradient, g(P);

obtaining the value of recording power, Ps, which coincide with the specific number, S, presently selected;

selecting a specific number, R, based on thus obtained recording power, Ps, from the numbers in the range of 1.0 to 1.7;

and

multiplying the recording power, Ps, by the specific number, R, whereby an optimum recording power, P_0, is obtained,

(2) an optical information recording medium utilized in the method described in (1) for carrying out recording and reading out operations of information data, in which the recording medium contains the information recorded in advance therein corresponding to the values, S and R, specified by the method (1),

(3) in the optical information recording medium values described in (2), the values, S and R, are $1.2 \leq S \leq 1.4$, and $1.1 \leq R \leq 1.3$, respectively,

(4) an optical information recording medium utilized in the method described in (1) for carrying out recording and reading out operations of information data, in which the recording medium contains the information regarding P_t value recorded in advance therein, the P_t value corresponding to the optimum recording power, P_0, specified by the method described in (1), and

(5) the phase-change optical recording medium described in any one of the above sections (2) through (4), in which the recording medium is characterized by being recordable at a recording velocity ranging from 4.8 m/sec to 14.0 m/sec.

[0005]

[DESCRIPTION OF THE PREFERRED EMBODIMENTS]

Preferred embodiments will be detailed herein below with respect to the methods and the optical information recording medium disclosed herein.

FIG. 1 is a section view illustrating an optical recording

medium disclosed herein.

Referring to FIG. 1, the optical recording medium in the present disclosure primarily includes

a supporting substrate 1 provided with guiding grooves, and the following layers formed contiguously on the supporting substrate in order as follows: A first dielectric layer 2, a recording layer 3, a second dielectric layer 4, a reflective/ heat dissipating layer 5, and an overcoat layer 6.

[0006]

Suitable materials for forming the transparent substrate 21 include in general resins which are preferably employed for its satisfactory moldability and low costs.

Specific examples of the resins include polycarbonate resins, acrylic resins, epoxy resins, polystyrene resins, acrylonitrile-styrene copolymeric resins, polyethylene resins, polypropylene resins, silicone resins, fluororesins, acrylonitrile-butadiene-styrene (ABS) resins and urethane resins. Of these, polycarbonate resins and acrylic resins are preferably used for their excellent moldability, optical properties and relatively low costs.

[0007]

As the materials suitable for forming the recording layer 3, guaternary phase-change recording materials containing Ag, In, Sb and Te, as major components, are preferably used for their excellent properties with respect to the sensitivity and speed of recording (i.e., bringing into the amorphous state), also sensitivity and speed of erasing (i.e., bringing into the crystalline state), and erasure ratios.

Since the Ag/ In/ Sb/ Te material has its specific optimum linear recording velocity depending on the composition thereof, it is preferable for the component to be suitably adjusted depending on the recording velocity at which the material is utilized for the recording. In addition, the recording material may be added with other elements, or impurities, to further improve these recording properties and media reliability.

Examples of the impurities preferably include those selected from the group consisting of B, N, C, P and Si, which are disclosed in Japanese Laid-Open Patent Application No. 5-158732, and another group consisting of O, S, Se, Al, Ti, V, Mn, Fe, Co, Ni, Cu, Zn, Ga, Sn, Pd, Pt and Au.

[0008]

The first and second protective layers, 2 and 4, are formed primarily consisting of dielectric materials. Examples of the dielectric materials include oxides such as SiO, SiO_2, ZnO, SnO_2, Al_2O_3, TiO_2, In_2O_3, MgO and ZrO_2; nitrides such as Si_3N_4, AlN, TiN, BN and ZrN; sulfides such as ZnS, In_2S_3 and TaS_4; carbides such as SiC, TaC, B_4C, WC, TiC and ZrC; diamond-like carbon, and mixtures thereof.

These materials may be used individually and in combination thereof, and they may further include impurities, where relevant. While the dielectric layers may be formed to have a multilayered structure, their melting temperatures are preferably higher than that of the recording layer.

The first and second protective layers 2,4 can be formed by, for example, vacuum evaporation, sputtering, plasma CVD, light assisted CVD, ion plating, or electron beam evaporation, or other

similar methods. Of these, the sputtering method is preferably utilized for its excellent productivity and properties of resultant layers.

The second protective layer 4 preferably has a thickness ranging from 15 nm to 45 nm, more preferably from 20 nm to 40 nm. When the thickness thereof is smaller than 15 nm, the layer cannot serve as a heat resisting protective layer, while the thickness of larger 45 nm causes several difficulties such as peeling-off at interlayer portions with relative ease after recording at low linear velocity ranging from 1.2 to 5.6 m/sec, and the reduction in repetitive recording sensitivity.

[0009]

As the materials suitable for forming the reflective/ heat dissipating layer 5, there used are metals such as Al, Au, Ag and Cu and alloys thereof. Although the reflective/ heat dissipating layer 5 need not be always provided in the recording medium, it is preferable for the layer to serve for dissipating the heat, thereby alleviating undue overall heat load on the recording medium.

The reflective/ heat dissipating layer 5 can be formed by, for example, vacuum evaporation, sputtering, plasma CVD, light assisted CVD, ion plating, electron beam evaporation, or other similar methods. In order for the reflective layer 5 to properly serve as a heat dissipating layer, the thickness thereof is preferably ranging from 70 nm to 180 nm, more preferably from 70 nm to 180 nm.

[0010]

The protective layer 6 is preferably formed to serve as an

antioxidant layer, which is generally consisting of ultraviolet curing resins disposed by spin coating and then cured under ultraviolet irradiation.

The thickness of the protective layer 6 is preferably ranging from 7 to 15 μm. The layer thickness smaller than 7 μm may result in the increase of C1 errors after affixing an overlying printed layer, while the thickness larger than 15 μm tends to cause the increase in internal stress which considerably influences mechanical properties of the recording disc.

[0011]

As electromagnetic radiation and energetic beams useful for initializing, recording, reading-out, or erasing the recording medium disclosed herein, laser light, ultraviolet light, visible light, infrared light or microwave radiation may be utilized. Of these radiations and beams, light beams from a semiconductor laser device are preferably used for its smallness in device size and compactness.

[0012]

FIG. 2 illustrates the pulse shape of input light beams of 5T width applied to the phase-change recording medium according to the embodiment disclosed herein. FIG. 3 illustrates the pulse shape of input light beams. FIG. 4 is a block diagram illustrating the major units of the record/ readout system disclosed herein.

Referring to FIG. 4, the record/ readout system disclosed herein is configured to carry out record/ readout operations of information data onto an optical recording medium 11, as follows: Rotating the recording medium 11 including a phase-change

optical recording disc by a driving mechanism 12 equipped with a spindle motor, activating a light source including a semiconductor laser device by a laser driving circuit 14 used as a light source driving unit, focusing laser beams onto the optical recording medium 11 by an optical system (not shown), irradiating and thereby inducing the phase transition in the recording layer, and receiving light beams reflected from the recording medium 11 with an optical pickup 13, whereby the record/ readout operations onto the optical recording medium 11 are achieved.

As described above, the write/readout system enables to carry out rewriting as well as the record/ readout operations of information data onto an optical recording medium 1 by inducing the phase transition in the recording layer through the laser beam irradiation onto the optical recording medium. In addition, the record / readout system is also provided with a plurality of additional units such as, for example, one for modulating information data signals to be recorded by a modulation unit and the other for recording the signals into the recording medium by the record/ readout pickup.

This recording unit including the optical pickup writes the information data in terms of the width of recorded 'marks', that is generally referred to as the pulse width modulation (PWM) method. Also, data signals to be recorded are modulated through the modulation unit using clock signals according to either the eight-to-four modulation (EFM) method or modified methods thereof, which are effectively utilized in the data recording for rewritable compact discs, for example.

[0013]

In data recording into the phase-change recording medium, a "1" signal (i.e., 1 in binary) is made, in general, by forming amorphous portions in the recording layer in the recording medium, which is carried out, in turn, by elevating temperature of the recording layer portion higher than its melting point and subsequently lowering the temperature at a rate large enough to form the amorphous phase.

The data recording can be achieved using a series of laser pulses exposed to the recording medium. Namely, the pulse fp operates to raise the temperature of recording layer portion higher than its melting point to thereby form the front portion of the recorded mark, the pulse mp retains the thus raised temperature to thereby form the middle portion of the recorded mark, and the pulse op lowers the temperature of recording layer portion to form the rear portion of the recorded mark.

By appropriately changing the linear velocity of the rotating recording medium, the amount of beam irradiation onto the recording medium varies, and also changes the speed of the above-mentioned raising and lowering the temperature of the recording layer portions. As a result, the speeds of raising and subsequent lowering the temperature of recording layer portions can appropriately be adjusted by varying the linear velocity of the rotating recording medium.

Further, the information pertinent to recorded data by the PWM method is placed at the edge portions of the recorded marks. Therefore, in order to prevent either smearing at the boundary between recorded and non-recorded portions on the recording

layer, or undue erasing caused by the crystallization of the amorphous recorded portions, it is important to prevent undesirable heating of the portions other than those to be recorded.

This smearing prevention, or the distinction between the portions to be recorded and to be retained at lower ordinary temperature, may be achieved by suppressing both undue heat generation at the recording layer portions and controlling heat conduction in the recording layer. By achieving the distinction between the recorded and non-recorded portions with the above noted measures, excellent information data signals with reduced jitter values can be obtained.

[0014]

[EXAMPLE 1]

A recording medium was prepared including at least the following layers: $SiO_2 \cdot ZnS$ layer (90 nm)/ AgInSbTe layer (18 nm)/ $SiO_2 \cdot ZnS$ layer (32 nm)/ Al alloy layer (160 nm^2).

The thus formed recording medium was subsequently subjected to data recording with linear recording velocity of 12.0 m/sec by means of an optical pickup unit having an aperture of NA 0.5 and laser emission of 790 nm in wavelength. In addition, the signals generated after the EFM method were input for data recording.

From the results in FIG. 3, the satisfactory values were found as S = 1.25, R = 1.20, thereby leading to Ps = 18 mW. As a result, the optimum was obtained as P_0 = 21.6 mW.

[0015]

[EXAMPLE 2]

Another recording medium was prepared in a similar manner to that of Example 1. In addition, information on S and R values, corresponding to the above noted relations S = 1.25 and R = 1.20, are recorded in advance in the recording medium.

The thus recorded information is subsequently readout to be utilized as the parameters for selecting an optimum recording power. Using the above noted parameters, the optimum was then found as $P_0 = 21.8$ mW. In addition, repetitive recording cycle steps were carried out with this recording power, whereby the recording was achieved with sufficient stability without deteriorating the readout signal quality.

[0016]

[Advantages of the Invention]

According to claim 1 in the present disclosure, the setting of optimum recording power can suitably be carried out for respective record/·readout apparatuses in the manufacturing line with practically sufficient accuracy with relative ease, since the optimum recording power is suitably determined for the respective apparatuses without affected the offset caused between the apparatuses in either between recording signal amplitudes, m, and recording powers, P, or among the amplitudes themselves.

According to claim 2 in the present disclosure, there become feasible are to select recording power properly reflecting physical characteristics of the recording medium, and to carry out recording steps with thus selected power, at which excellent

repetitive recording results can be expected, since the information corresponding to S and R values specified by the method in claim 1 is recorded in advance in the recording layer.

According to claim 3 in the present disclosure, the errors in recorded signals can be reduced to the level small enough for the practical purpose, the deterioration in recorded signal quality can also be reduced after repetitive recording cycle steps, since the values are specified to be $1.2 \leq S \leq 1.4$, and $1.1 \leq R \leq 1.3$ for the optical recording medium.

According to claim 4 in the present disclosure, optimum recording power can be determined with relative ease for arbitrary combinations of various optical recording media and record/ readout apparatuses, since the information regarding P_t value to be used in the method described in claim 1 is recorded in advance in the recording layer.

According to claim 5 in the present disclosure, stable recording becomes feasible of high quality signals at high recording speeds on the optical recording medium described in claims 2 through 4, since PWM recording is feasible at a recording velocity ranging from 4.8 m/sec to 14.0 m/sec.

[Brief Description of the Drawings]

[FIG. 1]

A schematic cross-sectional view illustrating an optical recording medium disclosed herein.

[FIG. 2]

A schematic drawing illustrating a pulse signal with 5T width applied to a phase-change recording medium by a record/

readout apparatus described in the present disclosure.

[FIG. 3]

A schematic drawing illustrating the shape of a series of input pulses during recording steps.

[FIG. 4]

A block diagram illustrating the major units of the phase-change information record/ readout system disclosed herein.

[Name of Document] Drawings

FIGS. 1 through 4.

[Name of Document] Abstract of the Disclosure

[Abstract]

[Object of the Invention]

To provide a method and an optical recording medium, effectively implementing recording steps at recording beam power in the range of as large as 15 mW to 18 mW, when a series of information data are recorded with recording power, P, of laser beam consecutively varied to generate a recorded pattern including low and high reflective portions.

[Means for Solving the Problems]

A method for carrying out recording and reading out operations of information data onto an optical recording medium through the phase change induced in a recording layer included in the recording medium by laser beam irradiation, including the steps of:

recording a series of information data, as test recording runs, with recording power of laser beam consecutively varied in the range of 15 mW to 18 mW to thereby generate a recorded pattern including low and high reflective portions;

reading out the thus test recorded signals to obtain recorded signal amplitude, m, corresponding to the recording power, P;

calculating a normalized gradient, g(P), using the equation, $g(P)= (m/\Delta m)/(P/\Delta P)$, where ΔP is an infinitesimal change in the vicinity of P, and Δm is an infinitesimal change in the vicinity of m; determining an optimum recording power, after judging adequacy of the magnitude of the recording power based on thus calculated normalized gradient, g(P);

selecting a specific number, S, from the numbers in the range of 0.2 to 2.0 based on the calculated normalized gradient, g(P);

obtaining the value of recording power, Ps, which coincide with the specific number, S, presently selected;

selecting a specific number, R, based on thus obtained recording power, Ps, from the numbers in the range of 1.0 to 1.7; and

multiplying the recording power, Ps, by the specific number, R, whereby an optimum recording power, P_0, is obtained.

[Selected Drawing] None

FIG. 1

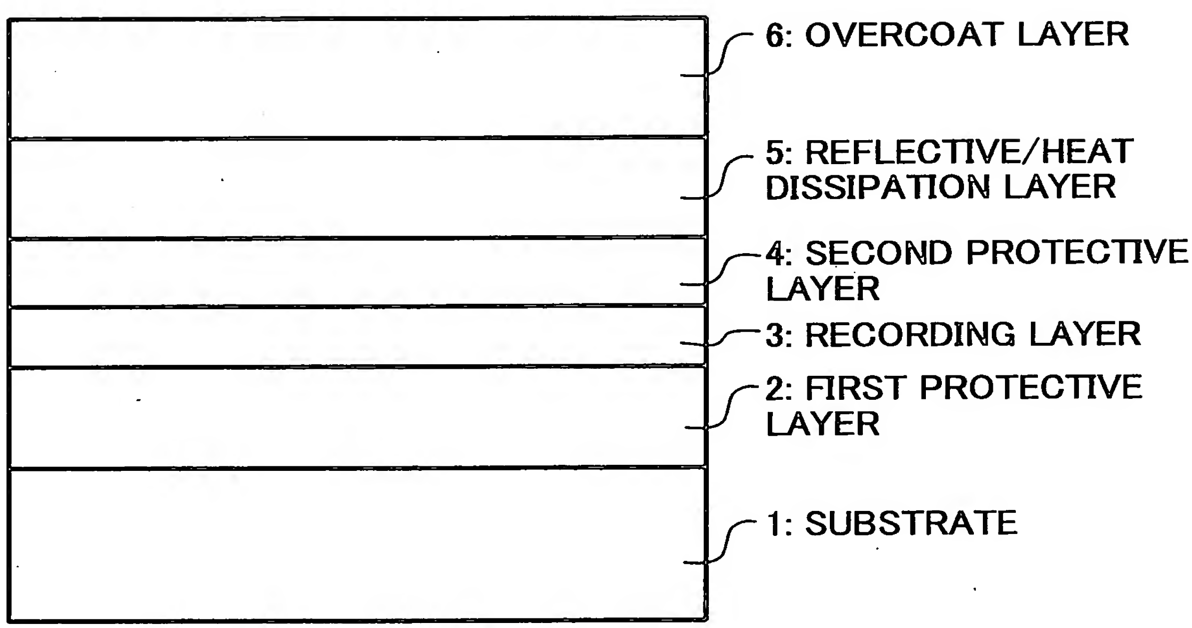
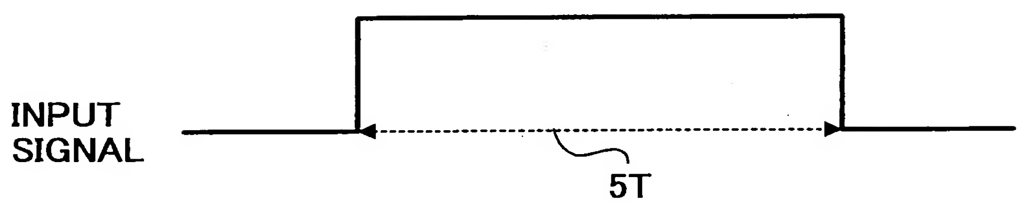
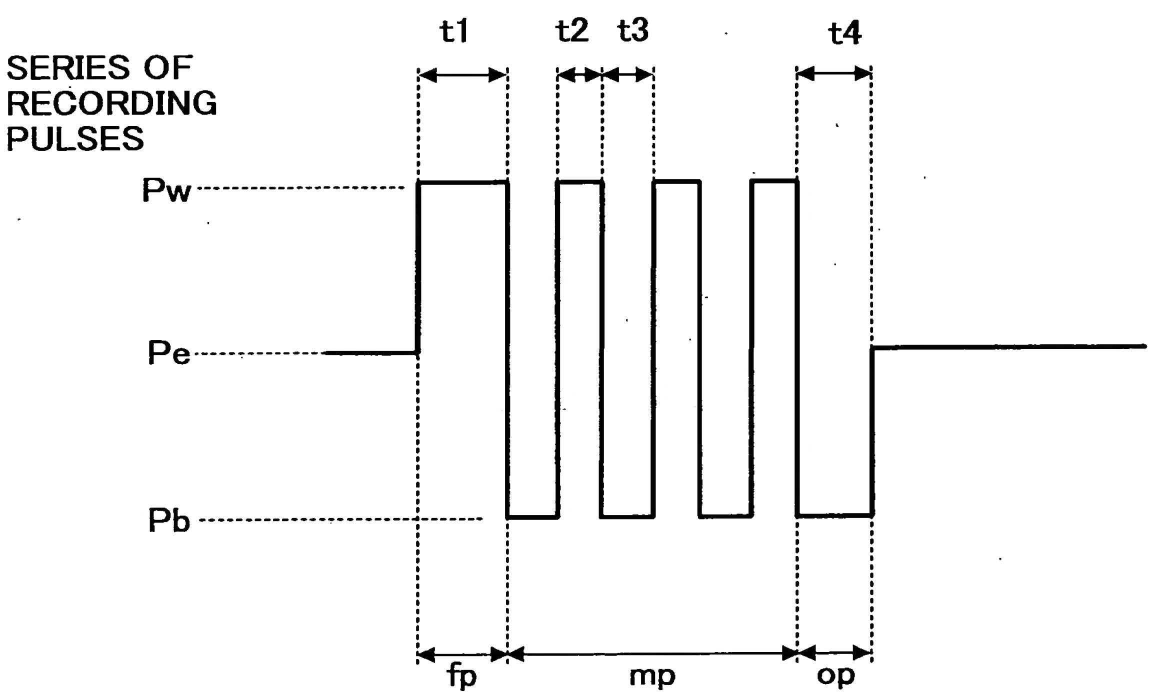

6: OVERCOAT LAYER
5: REFLECTIVE/HEAT DISSIPATION LAYER
4: SECOND PROTECTIVE LAYER
3: RECORDING LAYER
2: FIRST PROTECTIVE LAYER
1: SUBSTRATE

FIG. 2



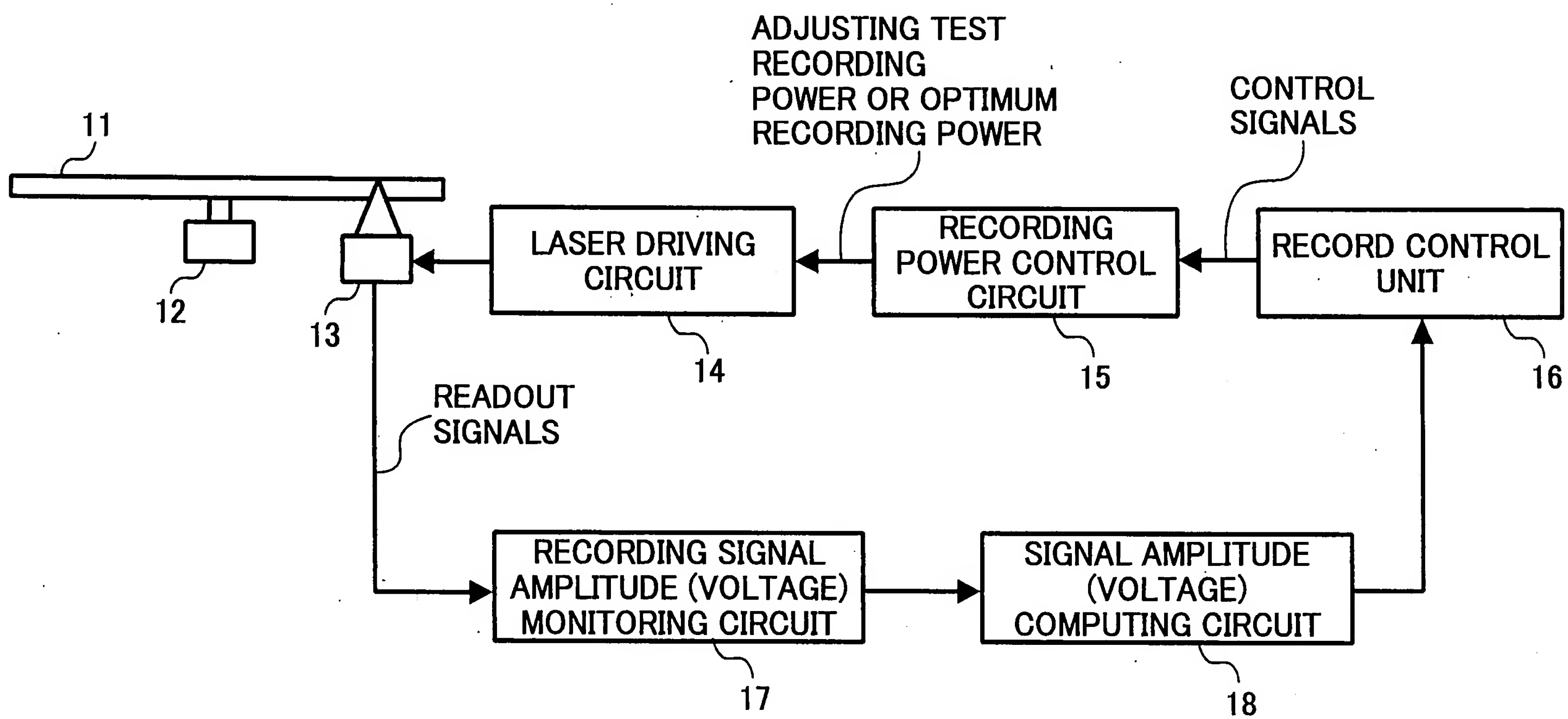
INPUT
SIGNAL
5T

FIG. 3



t1
t2
t3
t4
SERIES OF
RECORDING
PULSES
Pw
Pe
Pb
fp
mp
op

FIG. 4



11
12
13
LASER DRIVING CIRCUIT
14
ADJUSTING TEST RECORDING POWER OR OPTIMUM RECORDING POWER
RECORDING POWER CONTROL CIRCUIT
15
CONTROL SIGNALS
RECORD CONTROL UNIT
16
READOUT SIGNALS
RECORDING SIGNAL AMPLITUDE (VOLTAGE) MONITORING CIRCUIT
17
SIGNAL AMPLITUDE (VOLTAGE) COMPUTING CIRCUIT
18